November 2002 Roadway Research Notes No. 4

Construction Analysis for Pavement Rehabilitation Strategies (CA4PRS) Software

Combining Pavement Engineering, Construction Productivity Analysis, and Traffic Simulation to Expedite Major Freeway Reconstruction Projects.

Caltrans

institute of transportation studies
pavement research center

ROADWAY RESEARCH NOTES is a joint effort of the California Department of Transportation, Division of Research and Innovation and the University of California Pavement Research Center (PRC) with the purpose of sharing pavement research results and technology gained from PRC projects.

The Problem

For the rehabilitation of urban freeways with large volumes of heavy trucks, the most desirable pavement section is one that provides long life (at least 30 years) and minimizes subsequent traffic delays resulting from maintenance and rehabilitation activities ("get in, get out, stay out"). Long life pavements often require advanced pavement engineering concepts, materials, and pavement analysis procedures to arrive at optimal thicknesses. However, due to traffic delay concerns, limitations are often placed on construction closures, so minimizing construction time is also a significant objective.

Devising an optimal solution for a specific rehabilitation effort requires combining developments in pavement engineering, construction productivity analysis, and traffic simulation. Together, these are used to balance the traffic delay and construction schedule for the rehabilitation while considering different construction windows.

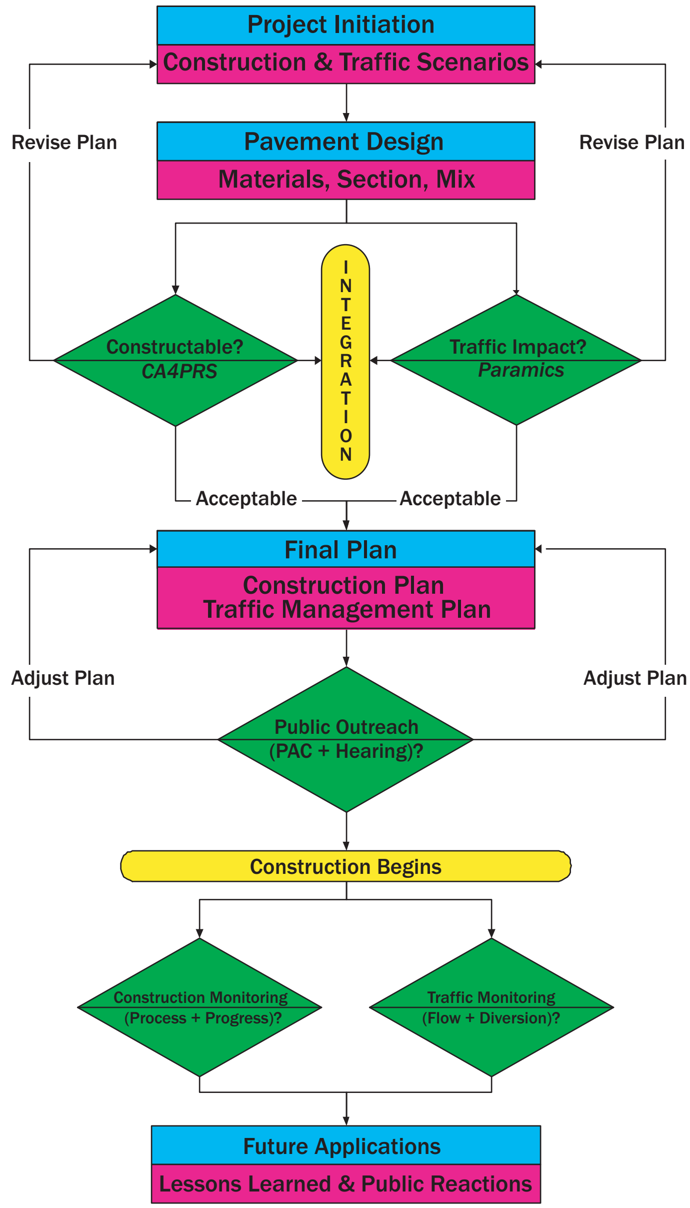
Response to Problem

Since its inception in 1994, the Department of Research and Innovation Pavement Program at the Pavement Research Center has devoted substantial effort to development of improved pavement design and rehabilitation methodology for more effective use of existing and new materials.

Construction productivity and traffic simulation have been addressed more recently as Caltrans has moved forward with the Long Life Pavement Rehabilitation Program. This has been achieved through development of the *CA4PRS* (Construction Analysis for Pavement Rehabilitation Strategies) software and utilization of Paramics, a microtraffic simulation program.

The development of the *CA4PRS* software resulted from observation of engineers with different expertise and responsibilities struggling to estimate the effects of their individual decisions on the other elements of a project. For example, materials engineers may select very expensive materials that gain strength quickly. However, a decision of this type may be made without knowledge of whether rapid material strength gain will improve construction productivity and reduce traffic delay sufficiently to justify the additional cost. It was also observed that no tools were available for estimating construction productivity through the application of well-known construction management methods, such as the critical path method (CPM) and linear programming techniques.

The use of Paramics resulted from discussions with traffic engineers responsible for assigning construction windows for urban freeway reconstruction. It appeared that these engineers relied primarily on experience and simple models that did not consider delay impacts of the highway and street network surrounding the project site. It became apparent that Caltrans and other road agencies needed to have more reliable data in order to communicate and negotiate in good faith with residents and businesses that would feel the effects of the construction and traffic delays. The general framework for this approach is shown below.



Framework for the integration of the construction analysis with traffic delay analysis of urban freeway reconstruction.

What Is *CA4PRS*?

CA4PRS is a software program designed to estimate the length of freeway that can be rehabilitated or reconstructed within a set of constraints. *CA4PRS* considers "what-if" scenarios for major parameters and constraints such as:

- Construction windows: 7- and 10-hour nighttime closures; 55-hour weekend closures; continuous weekday closures; any other closure windows required for a specific project;
- Lane closure tactics: partial closures; full closures (counter flow traffic);
- Strategy type: concrete (portland cement concrete or fast setting hydraulic cement concrete) slab replacement strategies; crack, seat, and asphalt overlay and full-depth asphalt concrete replacement strategies;
- Material constraints: mix design and curing time (concrete) and cooling time (asphalt)
- Pavement structural section profile: thickness of concrete slab or asphalt concrete layers;
- Concrete pavement design: widened truck lane, various base types (lean concrete base or asphalt concrete base);
- Resource constraints for the contractor: location, capacity, and available pavement equipment;
- Scheduling constraints: mobilization, demobilization, and traffic control.

The proposed work plan, CPM schedules, resource availability, and traffic pattern of the construction equipment are the main inputs to the analysis. The resource availability and construction traffic patterns are treated as constants in the deterministic analysis module, and treated as random variables in the probabilistic (stochastic) analysis module, which considers variability of the inputs.

CA4PRS can also be integrated and combined with a traffic simulation program. By analyzing potential construction and traffic scenarios, the software can provide clear, quantitative estimates of the optimal (most cost-effective) construction management and traffic control plans. The software can also evaluate different pavement structures and construction windows for construction duration. When combined with traffic delay simulation, this permits determination of which pavement structures maximize construction speed without creating unacceptable traffic delays. It also permits evaluation of the impact of various traffic handling tactics on construction duration, resulting in minimum total traffic delay. This data is vital to achieving the three competing goals of longer life pavement, faster construction, and less traffic delay during freeway reconstruction and rehabilitation projects.

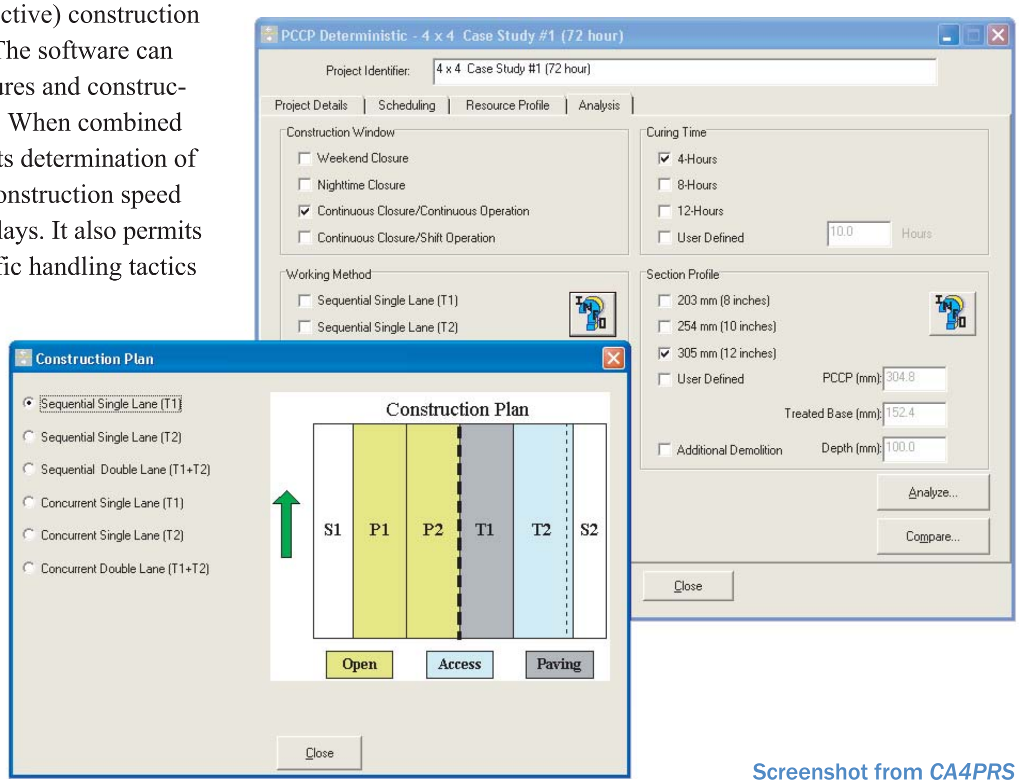
The software has been verified on I-10 in Pomona where Long Life Concrete pavement was placed in a 55-hour weekend closure. It has also been used to evaluate plans for the ongoing I-710 project in Long Beach where Asphalt Long Life pavement is to be placed during a series of weekend closures. The integration of pavement, construction, and traffic engineering is also being applied to an ongoing project on I-15 in Devore (near San Bernardino) from the initial planning stages.

The models and analysis methods in *CA4PRS* were developed with Caltrans funding. The coding of the *CA4PRS* software has been funded by Caltrans and the Departments of Transportation of the states of Minnesota, Texas, and Washington.

What Is Microscopic Traffic Simulation?

Microscopic traffic simulation enables analysis of transportation networks in design, planning, or operation studies. The Paramics software can model large networks at a fine level of detail by considering individual vehicles and replicating the effects of congestion, variable driver behaviors, and the impact of various traffic management and information systems. Caltrans is already involved in an ambitious statewide program centered around Paramics, including training staff, developing district applications, and funding research and development.

Two ongoing projects funded by Caltrans, I-710 in Long Beach (District 7) and I-15 in San Bernardino (District 8), have illustrated the benefits of using Paramics as part of the traffic analysis for construction delays. The simulated areas cover the freeway construction zone and other roadways potentially affected by route diversion during reconstruction.



Screenshot from *CA4PRS*

Microscopic simulation can be used to address such critical questions as:

- How should mainline freeway and ramp closures be planned to minimize the traffic delays caused by the reconstruction activities?
- What kind of traffic control and information strategies should be included in the traffic management plan to minimize the overall traffic delay during the reconstruction?
- What is the quantitative traffic impact of construction on the freeway and surrounding area?

Demonstration Project: Reconstruction of I-15 at Devore (Caltrans District 8)

This project is located on I-15 between I-10 and I-215 near San Bernardino (average daily traffic is about 110,000 with 9 percent trucks) and has a total length of 17 lane-kilometers (4.2 km × 2 lanes × 2 directions). There are two segments in the project: Segment 1 consisting of 4 lanes and Segment 2 consisting of 3 lanes. The existing pavement is 200 mm (8 in.) of concrete with 100 mm (4 in.) of cement treated base. The new pavement will consist of 290 mm (12 in.) of Type III high early strength concrete (reaches opening strength in 12 hours) with 150 mm (6 in.) of asphalt concrete base.

The evaluation of the total cost (construction cost + traffic handling cost + total user delay cost) based on the construction productivity and traffic analyses is being applied during the project's initial stages. The following table shows the results of some of the scenarios being investigated. Based on the overall comparison and justification, Caltrans District 8 has decided to use continuous closures during weekdays, with durations between 72 and 96 hours depending on the length of the segment.

The next step is to develop the most efficient traffic plan for managing traffic during construction based on traffic simulation analysis, and to develop a presentation of the results as part of the project's public outreach and information program.

Integrated Comparison of Construction Schedule and Traffic Delay for the I-15 Devore Project

Construction Scenario	Schedule Comparison		Cost Comparison ($M)			Max. Peak Delay (min.)
	Total Closures	Closure Hours	Agency Cost	User Delay	Total Cost	
72-Hour Weekday Continuous	8	512	12.6	5.6	18.2	75
55-Hour Weekend Continuous	10	550	15.1	14.2	29.3	195
1 Roadbed Continuous	2	400	9.9	6.9	16.8	195
10-Hour Nighttime Closures	220	2,200	20.4	4.9	25.3	35

Who Should Use *CA4PRS*?

CA4PRS is useful to many sectors of the transportation industry:

- State highway agencies, especially during the planning and design stages when the information can be used to optimize pavement, construction and traffic scenarios; and
- Design engineers, construction engineers, consultants, and paving contractors during estimating and project control stages.

Selected References

Downloadable at:
www.its.berkeley.edu/pavementresearch

Lee, E. B., W. Ibbs, J. Harvey and J. Roesler. *Constructability and Productivity Analysis for Long Life Concrete Pavement Rehabilitation Strategies.* Report prepared for the California Department of Transportation. Pavement Research Center, Institute of Transportation Studies, University of California, Berkeley. Caltrans Report No. FHWA/CA/OR-2000/01. Sacramento, CA, 2000. (draft August, 1999).

Lee, E. B., W. Ibbs, J. Harvey, and J. Roesler. *Constructability and Productivity Analysis for Long Life Asphalt Concrete Pavement Rehabilitation Strategies.* Draft report prepared for the California Department of Transportation. Pavement Research Center, Institute of Transportation Studies, University of California, Berkeley. June 2001.

Lee, E. B., J. Roesler, J. Harvey and C. W. Ibbs. *Case Study of Urban Concrete Pavement Reconstruction and Traffic Management for the I-10 (Pomona, CA) Project*. Research Reports and Findings (Contract no: DTFH61-99-X-00008), FHWA/IPRF (Innovative Pavement Research Foundation). Falls Church, VA, 2000.

For More Information

EB Lee
phone: (510) 231- 5693
email: eblee@uclink4.berkeley.edu

John Harvey
phone: (530) 754-6409
email: jtharvey@ucdavis.edu

Michael Samadian, Caltrans Contract Monitor
phone: (916) 324-2048
email: michael_samadian@dot.ca.gov